International Journal of Textile and
Fashion Technology (IJTFT)
ISSN (P): 2250-2378; ISSN (E): 2319-4510
Vol. 7, Issue 6, Dec 2017, 15-24

TRANS STELLAR
•Journal Publications •Research Consultancy

METHODOLOGY FOR THE SELECTION OF THE FIBER LAYING TYPE IN THE MANUFACTURING OF A NON-WOVEN TEXTILE FROM THICK ALPACA FIBER

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ABSTRACT

The development of new textile products involves the selection of production processes that minimize costs and production times. This research exhibits a methodology for the selection of the fiber laying type in a non-woven manufacturing process that uses coarse alpaca fiber. The fiber laying types that were submitted to evaluation were: cross-laid, parallel-laid, interlaced and random-laid, from which the following factors were evaluated: quality of the final product, vertical tensile strength and assembly time. The methodology involves three main phases: (1) textile expert consulting, (2) laboratory tests and (3) factor weighting. The results indicated that the most convenient fiber laying method in accordance to the evaluation factors was cross-laid.

KEYWORDS: Non-Woven, Fiber Laying, Selection Methodology & Alpaca Fiber

Received: Nov 20, 2017; **Accepted:** Dec 05, 2017; **Published:** Dec 13, 2017; **Paper Id.:** IJTFTDEC20173

Original Article

INTRODUCTION

A non-woven textile is manufactured by creating a web with fiber entangled with each other through mechanical, thermal or chemical procedures, without being woven. A new process for the manufacture of non-woven textile products is currently being technified. This process requires, among others, the definition of the most optimal fiber laying process, which allows obtaining alpaca fiber panels with the minimal time and costs that complies with required technical specifications. There are mainly four types of nonwovens, of which, it is not know which one suits the new process the best. The objective of this research was the selection of the fiber laid technique that adapts the best to the necessity requirements given by the non-woven process.

THEORETICAL FRAMEWORK

- **Textile Fiber:** Natural or manufactured filaments which are the basic element of fabrics and textile structures (Celanese Acetate LLC., 2001). Manufactured fibers are fabricated industrially, most of them are artificial and another important group are synthetic. Natural origin fibers are divided in animal, vegetal and mineral fibers. (CENTRUM &PUCP, 2010).
- **Alpaca Fiber:** Type of fiber that is presented in diverse basic colors: beige, brown, grey and black tones (Sineace, s.f.); its appearance varies according to the alpaca breed they come from, like Suri or Huacaya alpaca, having the latter the following fleece characteristics: it is compact, spongy, it has bulk appearance with fine, soft and wavy fibers. Suri alpacas present great length fibers organized in hanging curls. (Hoffman y Fowler, 1995; Antonini et al., 2004 and FAO, 2005) cited by (E.C. Quispe et al., 2009).

- **Alpaca Fiber Properties:** (Mayhua et al., 2014) suggest that, this fiber is distinguished by its flexibility, softness to the touch, low flammability, allergenic capabilities and low felting capacity. (Agrobanco, 2012) mentions additional characteristics as: high moisture absorbance capacity, scaly structural surface, natural curl, high thermal resistance, dimensional and appearance stability. Some of the characteristics that were considered as influential for the research are mentioned subsequently:

a) **Finesse:** It oscillates between 18 and 40 microns, depending on the location in the alpaca were the fleece was extracted and its age.

b) **Length:** It varies in relation with the alpaca type and variety. The fiber length and its variability are also in relation with the alpaca's growth period.

b) **Longitud:** Varía en relación al tipo (Suri o Huacaya) o variedad. La longitud de fibra y su variabilidad está en relación al periodo de crecimiento de la misma (Table 1).

Table 1: Finesse and Lenght of Alpaca Fibers

Denomination	Microns	Average minimum lenght
Alpaca baby	Less than 23	65
Alpaca fleece	Between 23.1 & 26.5	70
Alpaca medium fleece	Between 26.6 & 29	70
Alpaca huarizo	Between 29.1 & 31.5	70
Alpaca gruesa	Higher than 31.5	70
Alpaca corta	-	Between 20 a 50

Source: NTP 231.301:2004

c) **Resistance:** The highest the N/ktex value, the most adequate will the fiber be for processing, for it will not break. Alpaca fiber has a high tensile strength with values higher than N/ktex.

d) **Softness:** Perceived by tact, when the contact of the fiber with the skin generates a softness sensation, depends on the fiber type (fine or coarse). It is affected by other factors like: fiber flakes, finesse and humidity (Asociación Internacional de la Alpaca, 2017).

e) **Grease:** Alpaca fleece is composed by fibers, grease, salts as sweat residue, vegetal matters, ground dust and epithelial waste in a 2-5% percentage of its total weight, which is low in comparison with wool (15-20%)(Agrobanco, 2012; Asociación Internacional de la Alpaca, 2017).

- **Alpaca Coarse Fibers:** Fibers with a higher than 31.5 microns diameter, mainly extracted from the pectoral area, extremities and head from the alpacas (Mayhua et al., 2014), while alpacas increase their age and size, its fiber tends to become coarser and more irregular. This fibers are characterized because they are rigid, rough, hard and resist wrinkling, and it has a higher lust than finer fibers (Codina, 1973) cited by (Mayhua et al, 2014). This fiber is generally used for the manufacture of handcraft, rugs, tapestries and other low-added-value products (Sanchez, 2017); reason why it presents a lower cost in comparison with the rest of the fiber qualities.

- **Textile Alternative Process:** Non-woven textile process recognized as an alternative process in the industry (Patel & Bhrambhatt, 2008), where the manufacture of fabrics from fibers consists of three stages: The formation or laying of a textile sheet, the joint of the fibers and final finishing processes.

Fiber Sheet Laying

a) **Cross-Laid:** The fibers are laid in two sheets; one has a horizontal direction while the other presents a vertical direction.

b) **Parallel-Laid:** Both sheets are laid on the same orientation. This process creates lightweight products, and it is known that by using this technique, the sheets are five to six times stronger throughout their length than along their width (Patel & Bhrambhatt, 2008).

c) **Interlaced:** Fiber strands are interlaced between each other to get the fiber sheet.

d) **Random-Laid:** Fibers, cut into small strands are shredded and placed in a rack to create the textile sheet. This kind of sheets has the same properties in every direction and is the cheapest to produce. This process is the most adequate for small length or residual fibers (Patel & Bhrambhatt, 2008).

Joint of the Fibers (Chemical or with Adhesives)

a) **Saturation Adhesive Link:** Consists in submerging the textile sheet, in a tub containing the binder, previously prepared, and pass it through a draining system, where pressure is exerted to remove the binder excess; this way, panel with little variety in their weight and rigidity are obtained (Patel & Bhrambhatt, 2008)

METHODOLOGY

The methodology for the selection of the best fiber laying type, to obtain a textile panel that complies with basic technical requirements of a new non-woven manufacturing process was constituted by three essential phases: Textile expert consulting, laboratory tests and factor weighting.

Textile Expert Consulting

The main objective of this first stage was to determine the different laying techniques, which will allow obtaining a uniform product without imperfections; and, the factors with which we will perform the final qualification. The consulted experts were a chemical engineer with over 30 years of experience in the textile sector, and a technician who developed the new-patented process for the manufacture of non-woven textiles. The main factors for evaluation identified are:

- **Quality:** The disposition of the fibers influences directly on the visual, tactile and functional quality of the product; being that, a bad-performed disposition could generate holes, which would not permit the adequate cohesion of fibers, thus creating a defective product. The technician owner of the process will perform the evaluation of the quality once the product is finished.
- **Vertical tensile strength:** Due to the application intended for the product, it must have a good vertical tensile strength so it becomes suitable.
- **Process time:** Time spent laying the fiber in the established measures.

The laying-techniques consulted biographically and recommended by the textile experts for the performance of these laboratory tests are:

- **Cross-Laid:** The fibers are disposed in two different sheets, one with vertical orientation and the other in horizontal orientation.

- **Parallel-Laid:** The fibers are disposed in two different sheets, with the same orientation.
- **Interlaced:** The fibers are disposed in two different sheets, interlaced under the criteria: "one up and one down" with the objective of creating a weave.
- **Random-Laid:** The disposition is in one sheet of shredded fibers.

Laboratory Tests

Considerations

- Coarse alpaca was the raw material used throughout all the tests performed.
- A textile binder with a concentration of 2% was used for fiber cohesion.
- A matrix that considers three representative samples for each kind of laying-techniques is the responsible for the evaluation of the final product.
- 115 x 60 cm textile panels were put together considering six strips of textile fibers for the shortest side (horizontal orientation) and eight strips of fiber for the longest side (vertical orientation) for the cross-laid, horizontal laid and random-laid. Six strips of textile fibers were used for both sheets of fibers for the parallel-laid, obtaining a similar weight among the 12 textile panels (203 gr. +/- 10%).
- According to the information gathering and expert consulting processes, it was determined that the only variable to be measured during the manufacture tests performed was the assembly time of the panels, due to all the other production variables do not depend on the laying-technique; however, the time of fiber preparation, weight of each fiber sheet and initial panel measurements were measured.

Tests

Cross-Laid

The process started by cutting eight sixty-centimeters and six one hundred and fifty-centimeter strips of fibers, weighting them and performing the fiber-laying process, creating a 115 x 60 panel. (See Tables 2, 3 and 4)

Table 2: Fiber-Laying Technique – Cross-Laid, Sample 01

Variable		Value	Image
Fiber Preparation Time		03:09	
Initial Weight (g)	**1° Sheet(g)**	108.06	
	2° Sheet(g)	77.66	
	Total (g)	185.72	
Assembly Time		13:24	
Measurements	**Lenght**	115.00	
	Width(cm)	60.00	
	Area (cm^2)	6900.00	

Table 3: Fiber-Laying Technique – Cross-Laid, Sample 02

Variable		Value	Image
Fiber Preparation Time (min)		03:27	
Initial Weight (g)	**1° Sheet(g)**	108.69	
	2° Sheet(g)	77.82	
	Total (g)	186.51	
Assembly Time		21:31	

Measurements	**Length(cm)**	115.00	
	Width(cm)	60.00	
	Area (cm^2)	6900.00	

Table 4: Fiber-Laying Technique – Cross-Laid, Sample 03

Variable		Value	Image
Fiber Preparation Time (min)			
Initial Weight (g)	**1° Sheet(g)**	110.67	
	2° Sheet(g)	83.88	
	Total (g)	194.55	
Assembly Time			
Measurements	**Length(cm)**	115.00	
	Width(cm)	60.00	
	Area(cm^2)	6900.00	

Once the 03 samples finished their assembly, they were submitted to the non-woven textile production process, obtaining compact panels that were sent to a certified textile laboratory for vertical and horizontal tensile strength tests (See Table 5)

Table 5: Tensile Strength Tests – Cross-Laid, Samples 01, 02 y 03

Variable	Sample	Value
Vertical Tensile Strength (N)	01	132.30
	02	151.22
	03	123.57
Horizontal Tensile Strength (N)	01	57.37
	02	67.18
	03	74.14

Parallel-Laid

The process started by cutting twelve one hundred and fifty-centimeter strips of fibers, weighting them and performing the fiber-laying process, creating a 115 x 60 panel. (See Tables N°6, 7 and 8).

Table 6: Fiber-Laying Technique – Parallel-Laid, Sample 01

Variable		Value	Image
Fiber Preparation Time (min)		03:04	
Initial Weight (g) 2° Capa (g)	**1° Sheet(g)**	110.24	
	2° Sheet(g)	109.98	
	Total (g)	220.22	
Assembly Time		18:29	
Measurements	**Length(cm)**	115.00	
	Width(cm)	60.00	
	Area (cm^2)	6900.00	

Table 7: Fiber-Laying Technique – Parallel-Laid, Sample 02

Variable		Value	Image
Fiber Preparation Time (min)		04:01	
Initial Weight (g)	**1° Sheet (g)**	105.12	
	2°Sheet (g)	101.41	
	Total (g)	206.53	
Assembly Time (min)		13:40	
Measurements	**Length (cm)**	115.00	
	Width (cm)	60.00	
	Area (cm^2)	6900.00	

Table 8: Fiber-Laying Technique – Parallel-Laid, Sample 03

Variable		Value	Image
Fiber Preparation Time (min)		04:07	
Initial Weight (g)	**1° Sheet (g)**	100.61	
	2° Sheet (g)	102.58	
	Total (g)	203.19	
Assembly Time (min)		13:45	
Measurements	**Length (cm)**	115.00	
	Width (cm)	60.00	
	Area (cm^2)	6900.00	

Once the 03 samples finished their assembly, they were submitted to the non-woven textile production process, obtaining compact panels that were sent to a certified textile laboratory for vertical and horizontal tensile strength tests (See Table°09)

Table 9: Tensile Strength Tests – Parallel-Laid, Samples 01, 02 y 03

Variable	Sample	Value
Vertical Tensile Strength (N)	01	161.42
	02	208.50
	03	181.04
Horizontal Tensile Strength (N)	01	17.55
	02	18.54
	03	17.75

Tendido "Entrelazado"

The process started by cutting eight sixty-centimeters and six one hundred and fifty-centimeter strips of fibers, weighting them and performing the fiber-laying process, creating a 115 x 60 panel. (See Tables °10, 11 and 12)

Table 10: Fiber-Laying Technique – Interlaced, Sample 01

Variable		Value	Image
Fiber Preparation Time (min)		03:50	
Initial Weight (g)	**1° Sheet (g)**	108.45	
	2° Sheet (g)	80.78	
	Total (g)	189.23	
Assembly Time (min)		23:30	
Measurements	**Length (cm)**	115.00	
	Width (cm)	60.00	
	Area (cm^2)	6900.00	

Table 11: Fiber-Laying Technique – Interlaced, Sample 02

Variable		Value	Image
Fiber Preparation Time (min)		04:22	
Initial Weight (g)	**1° Sheet (g)**	108.56	
	2° Sheet (g)	82.91	
	Total (g)	191.47	
Assembly Time (min)		28:20	
Measurements	**Length (cm)**	115.00	
	Width (cm)	60.00	
	Area (cm^2)	6900.00	

Table 12: Fiber-Laying Technique – Interlaced, Sample 03

Variable		Value	Image
Fiber Preparation Time (min)		03:38	
Initial weight (g)	**1° Sheet (g)**	108.08	
	2° Sheet (g)	79.73	
	Total (g)	187.81	
Assembly Time (min)		27:48	
Measurements	**Length (cm)**	115.00	
	Width (cm)	60.00	
	Area (cm^2)	6900.00	

Once the 03 samples finished their assembly, they were submitted to the non-woven textile production process, obtaining compact panels that were sent to a certified textile laboratory for vertical and horizontal tensile strength tests (See Table°13).

Table 13: Tensile Strength Tests – Interlaced, Samples 01, 02 y 03

Variable	Sample	Value
Vertical Tensile Strength (N)	01	67.28
	02	103.27
	03	73.06
Horizontal Tensile Strength (N)	01	65.71
	02	51.88
	03	68.55

Random-Laid

The process started by cutting eight sixty-centimeters and six one hundred and fifty-centimeter strips of fibers, weighting them and performing the fiber-laying process, creating a 115 x 60 panel. (See Tables N°14, 15 and 16).

Table 14: Fiber-Laying Technique – Random-Laid, Sample 01

Variable		Value	Image
Fiber Preparation Time (min)		03:56	
Initial Weight	**1° Sheet (g)**	106.22	
	2° Sheet (g)	80.13	
	Total (g)	186.35	
Assembly Time (min)		44:20	
Measurements	**Length (cm)**	115.00	
	Width (cm)	60.00	
	Area (cm^2)	6900.00	

Table 15: Fiber-Laying Technique – Random-Laid, Sample 02

Variable		Value	Image
Fiber Preparation Time (min)		04:12	
Initial Weight	**1° Sheet (g)**	105.63	
	2° Sheet (g)	82.35	
	Total (g)	187.98	
Assembly Time (min)		37:11	
Measurements	**Length (cm)**	115.00	
	Width (cm)	60.00	
	Area (cm^2)	6900.00	

Table 16: Fiber-Laying Technique – Random-Laid, Sample 03

Variable		Value	Image
Fiber Preparation Time (min)		03:43	
Initial Weight	**1° Sheet (g)**	108.78	
	2° Sheet (g)	80.12	
	Total (g)	188.90	
Assembly Time (min)		34:16	
Measurements	**Length (cm)**	115.00	
	Width (cm)	60.00	
	Area (cm^2)	6900.00	

Once the 03 samples finished their assembly, they were submitted to the non-woven textile production process, obtaining compact panels that were sent to a certified textile laboratory for vertical and horizontal tensile strength tests (See Table°17).

Table 17: Tensile Strength Tests – Random-Laid, Samples 01, 02 y 03

Variable	Sample	Value
Vertical Tensile Strength (N)	01	158.28
	02	144.46
	03	162.01
Horizontal Tensile Strength (N)	01	163.58
	02	182.70
	03	160.44

Summary of Obtained Data

In Table 18, the average of the controlled variables for all of the laying-techniques are shown

Table 18: Summary of the Average of the Observed Variables

Fiber-Laid Technique	Variable	Value
Cross-Laid	Fiber preparation time (min)	03:50
	Initial weight (g)	188.93
	Assembly time (min)	18:76
	Measurements (cm^2)	6900.00
Parallel-Laid	Fiber preparation time (min) (min)	0.3:73
	Initial weight (g)	209.98
	Assembly time (min)	15:30
	Measurements (cm^2)	6900.00
Interlaced	Fiber preparation time (min)	3:94
	Initial weight (g)	189.50
	Assembly time (min)	26:54
	Measurements (cm^2)	6900.00
Random-Laid	Fiber preparation time (min) (min)	3:95
	Initial weight (g)	187.74
	Assembly time (min)	38:59
	Measurements (cm^2)	6900.00

Factor Weighting

Weighting Matrix

For the selection of the most optimal fiber-laid technique, the factors identified in the expert consulting process were weighted, obtaining the matrix shown in Table 19.

Table 19: Factor Weighting for the Fiber-Laid Technique Selection

Factors	Quality	Vertical Tensile Strength	Horizontal Tensile Strength	Assembly Time	Total	Weight
Quality	3	4	4	4	15	0.3127
Vertical Tensile Strength	2	3	3	3	11	0.2291
Horizontal Tensile Strength	2	3	3	3	11	0.2291
Assembly Time	2	3	3	3	11	0.2291
Total					**48**	**1.00**

Footnote: The qualification was performed according to the following values: 1-Much less important than, 2- Less important than, 3- As important as, 4- More important than, 5-Much more important than.

RESULTS

Table 20 shows the results of the fiber-laying types against the factors.

Table 20: Factorial Analysis

Fiber-Laying Technique	Quality	Vertical Tensile Strength	Horizontal Tensile Strength	Assembly Time
Cross-Laid	The panel is well distributed and uniform all over its surface. It presents efficient quality.	135.70 N	66.23 N	Does not require a lot of time, but implies medium effort.
Parallel-Laid	Few empty spaces were found due to the fiber are laid on the same orientation.	183.65 N	17.95 N	Requires little time and its is easy to assemble.
Interlaced	Deficient quality, a lot of blank spaces can be seen in the fiber intersections.	81.20 N	62.05 N	Requires a lot of time and it is complicated to assemble.
Random-Laid	No uniformity was found. Holes are notorious.	154.92 N	168.91 N	Requires a lot of attention and it is laborious.

According to the results obtained, the cross-laid technique was selected, this can be seen in Table 21.

Table 21: Evaluation and Selection of the Fiber-Laying Technique for the Manufacture of Non-Woven Textiles

Factors/Fiber-Laid Technique	Punctuation	Cross-Laid	Parallel-Laid	Interlaced	Random
Quality	0.3127	4	3	2	3
Vertical Tensile Strength	0.2291	4	5	3	5
Horizontal Tensile strength	0.2291	3	2	3	5
Assembly time	0.2291	4	5	3	2
Total	1.00	3.77	3.69	2.69	3.69

Footnote: The qualification was performed according to the following values: 1- Deficient, 2- Bad, 3- Standard, 4- Good, 5-Excelent

CONCLUSIONS

- The design and application of an adequate methodology for the selection of the most optimal fiber-laying technique for a non-woven manufacturing process is fundamental in order to obtain good results.

- The quality of the product is the most influential factor, because it evaluates whether the product is suitable for its final use or not.
- According to the obtained results, the most optimal fiber-laying technique for the manufacture of non-woven textiles using coarse alpaca fiber was identified.

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